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PROJECT THOR

HISTORY AND CURRENT ACTIVITIES

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"PROJECT THOR"

History and Current Activities

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ﹶ   "Project Thor"

In 1947, an extensive program was started at Aberdeen Proving Ground, Maryland to correlate the mass and velocity of shell fragments with the probability of damage to an aircraft component. For this experiment, nine controlled fragmentation shell types, representing three fragment masses, each with three fragment velocities, were fired in selected positions about 152 B-25 aircraft. Each fragment which hit the target was considered separately, and the damage it caused to the aircraft components and dummy personnel was determined by a group of trained assessors.

In April 1948, the Johns Hopkins University, Institute for Cooperative Research was asked to undertake, as a research project, the statistical analysis and evaluation of approximately 70,000 fragment strikes resulting from the Aberdeen experiment. Thus, Project Thor came into existence under the joint sponsorship of the Philadelphia Ordnance District, Department of the Army, and the Ballistic Research Laboratories of Aberdeen Proving Ground.

A list of Thor publications will be found at the end of the text.

In its first technical report, Project Thor computed, for various directional groupings, conditional probabilities of damage in categories "K", "A", and "B" on aircraft structural components, engines and engine sub-components, fuel system, and personnel. These probabilities were then correlated with the masses and velocities of the fragments causing the damage.

A natural extension of the original problem was to determine

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the reliability of predicting the lethality of any service shell with known fragmentation characteristics, against the same target. Fortunately, the Ballistic Research Laboratories had already determined the effectiveness of 75 mm and 105 mm HE shell fired against the B-25 aircraft. Consequently, the results of these firings were compared with predicted values for the effectiveness of these rounds using an energy criterion. The second technical report indicated that here indeed was a reliable and economical method for computing the probabilities of damage to aircraft components by service shell. Combinations of damage to components needed to defeat the target in a particular damage category were determined. The probability of inflicting such damage on the aircraft was obtained by suitable treatment of the component kill probabilities.

These results were not restricted to the B-25 aircraft. This type had been selected merely because it was available in large numbers and because it was typical of all aircraft; that is, it contained engines, a fuel system, personnel, and structure. The differences among aircraft are those of location, number, size, and design of components. With care, these differences can be resolved so that the vulnerability of any conventional aircraft to a given type of high explosive shell can be predetermined. An application to the B-29 was made in the third technical report which calculated the vulnerability of this bomber to 120 mm HE shell for two categories of damage.

In the fourth technical report analytical techniques were derived for computing the probability of aircraft kill for a class of similar missile-aircraft engagements when the following data are known for some particular member of the class: (a) the probability of missile

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burst at any point about the aircraft, and (b) the probability of aircraft kill by a burst at that point. An application of the theory was made to determine the variation in kill probability of aircraft and aircraft components with fragment size and fragment velocity. The engagement involved a 30.75 lb warhead and a B-29.

The Aberdeen firing records were reexamined in greater detail for damage to specific aircraft components such as the fuel system, pilots, and certain structural items.

Damage to the B-25 fuel system was analyzed in BRL MR 535. The probability that a strike would cause a fire was determined for gasoline-filled and gasoline fume-filled tanks and for fuel lines. Previously, the whole fuel system had been considered as a single vulnerable component.

The vulnerable areas of the pilot and copilot as enclosed in B-25 armor were analyzed from a directional point of view and the results presented in BRL MR 538. The Aberdeen experiments on controlled fragmentation firings against B-25 bombers were used to determine perforation probabilities.

In BRL 763, probabilities of C damage (defeat of a specified mission) to the aircraft were calculated for three situations: (1) given a strike on any of the structures, (2) given a strike on a selected group of structures, and (3) given a strike on a specified structural item. Consideration was given to the direction of approach of the damaging fragment. Probabilities of hits on each structure were also determined for the first two situations mentioned.

In the fifth technical report, an application of the results

of previous reports was made. The probabilities of killing a jet bomber under attack by a guided missle were determined for several sets of parameters. A similar evaluation had been made of an engagement involving an earlier prototype of this missile with a B-29 target. Both evaluations employed the "Lotto Method" and equipment for simulating the burst point and target system.

The Ballistic Research Laboratories required information on the variation in presented area of a prone Chinese infantryman as a function of the angle of arrival of fragment or bullet. This relationship was determined by Project Thor in the sixth technical report with the aid of a photographic technique that had been used in the pilot vulnerable area study.

In the seventh technical report, a further application of early Thor reports was made for the evaluation of a 5"0 HVAR attack on a B-29 target. Here the rocket, equipped with an electrically-timed fuze, is fired from an F-86D approaching the B-29 head-on at 30,000 feet altitude. The optimum aiming plane for an "A" kill on the target was determined for an 1100 yard launch distance. The evaluation was made for the rocket warhead designed for (a) 60 grain fragments, (b) 16 inch length rod fragments, and (c) 8 inch length rod fragments. The results were tabulated and the three warheads compared. Rod lethality data were obtained from external sources. In the appendix of this report appears a graphical solution of the time lapse between missile burst and fragment impact. A significant outcome of this and other evaluations has been the suggestions made to improve aircraft design and weapons.

Conditional probabilities of fire, "A"-kill, "B"-kill,

penetration and leakage for various conditions of strike have been

computed for fragments of various weights and velocities emitted from

controlled fragmentation shell exploded against B-25 aircraft fuel

components. The above probabilities have been calculated for gasoline-

filled tanks for strikes on the top, bottom, and sides, for all strikes

above the fuel level, for all strikes below the fuel level, and for a

combination of all strikes above and below the fuel level. For

gasoline-filled lines the same probabilities have been calculated for

metal lines, for self-sealing hose, and for the combination of metal

lines and self-sealing hose. The probabilities have also been calcu-

lated for gasoline fume-filled tanks and for gasoline fume-filled lines

and for self-sealing hose and metal lines combined. Several supple-

mentary studies pertaining to gasoline-filled tanks have also been

made. The results of this study are published in BRL 836.

The eighth technical report was designed as a supplement

to Project Thor Technical Report No. 1. Presented in this report are

the results of an analysis of data from the High Velocity Controlled

Fragmentation Program conducted at Aberdeen Proving Ground subsequent

to the original Controlled Fragmentation shell firings. Three addition-

al shell types were employed, yielding striking velocities greater than

those previously employed.

The ninth technical report is a continuation of the seventh

technical report, in which results of an evaluation of a 5"0 HVAR were

published. This ninth report considers the tail-on attack on the B-29.

For the purposes of this report simulator techniques were altered some-

what to consider salvo problems.

In the tenth technical report, a method was given for

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evaluating on the Ordvac the effectiveness of specially designed rod fragmenting warheads against bombers. A comparison was made of the results of this method with those obtained from an evaluation made on a manual simulator under identical engagement conditions.

BRL MR 729 is also based on data obtained from firings of controlled fragmentation shell against B-25 bombers at Aberdeen Proving Ground. This report extends the study incorporated in the first and the eighth technical reports to include component kill probabilities as functions of fragment mass and velocity for several values of time after impact. This analysis covered all twelve shell types. In conjunction with this study the raw data of the firing records from the controlled fragmentation program conducted at Aberdeen Proving Ground were reassessed by a team of assessors from A.P.G. Hence the conditional kill probabilities for "K", "A" and "B" damage in this report differ somewhat from those published in T. R. 1.

In the eleventh technical report the results of the vulnerability-time study of BRL MR 729 were applied to the 5"0 HVAR 60 grain cubical fragment vs. B-29 engagement, evaluated for "A" damage in Project Thor Technical Report No. 9. Essentially the same engagement assumptions and kill criteria used in T.R. 9 evaluation were used in this evaluation.

Since 1950, a Project Thor group has been engaged in the evaluation of a series of missile-bomber engagements. For fragmenting warheads, simulator equipment and techniques were used. The first simulator method used was developed by the Anti-Aircraft Section of the Ballistic Research Laboratories using "Lotto" methods. Several modifications were made in the equipment and techniques in order to adapt

the simulator to broader uses and reduce the time required for simulating engagements.

The first modification facilitated the location of warhead burst points and target positions.

For the evaluation of rod-fragmenting warheads two new type simulators were constructed. The first simulator was equipped with an adjustable periscope which enabled the operator to sight along a rod trajectory. The rod trajectories were chosen at random and the operator was able to determine whether a vulnerable component inter-sected a given trajectory. It was later found more efficient to project cross-slits of light along a rod trajectory and for this purpose a second simulator was designed with a projector replacing the peri-scope.

Recently a photoelectric simulator has been developed at Project Thor which greatly reduces the time formerly required to simulate the engagement between a fragmenting warhead and an aircraft target. In this simulator the vulnerable components of the target are represented by one or more light bulbs which when illuminated singly activate a photoelectric cell placed at the burst point. The corres-ponding component kill probabilities are then read from an ammeter which has been properly calibrated.

A simple analog computer has also been developed which enables the operator to combine the component kill probabilities rapidly. A salient feature of this computer is the facility with which kill probabilities can be provided for certain combinations of multiply vulnerable components, given a kill probability for each separate component. The computer now in operation at Project Thor is designed

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to yield the probability of killing at least three out of four engines and two out of two pilots. An extension to the computer is in the design stage which will provide engine kill probabilities for six engine aircraft for various engine kill criteria.

A report tentatively entitled A Photoelectric Engagement Simulator and An Analog Computer for Compounding Aircraft Kill Probabilities will be published shortly as a Project Thor Technical Report.

A hypothetical family of solid-propellant fin-stabilized rockets has been developed. A great deal of the background information for the design of the family was gathered by the Ballistic Research Laboratories. Values for a large number of rocket parameters covering wide ranges have been computed and the results expressed graphically. To simplify the presentation of results those parameters which were dependent upon the rocket caliber were expressed as ratios with respect to the caliber.

The motivation for the design of this family of rockets was the determination by evaluation of an optimum rocket or class of rockets for use in any specified combat situation. At present the effectiveness of these rockets as fighter armament against bomber targets is being evaluated. The present rocket launcher vehicle is assumed to possess the characteristics of the F-86D and the present bomber target is the B-29. The evaluation is being carried out by various methods of simulation all of which have been or will be described in Thor reports.

Although this family of rockets was constructed primarily to determine optimum rockets for different combat situations, its use need

not be so restricted. This family can be useful, for example, in the study of aim wander, salvo and ripple firing, and the duel problem.

In this connection a study has recently been made of an engagement between an F-86D carrying 24 2"75 rockets and a B-29 returning fire from its tail turret at 30,000 feet. Effects of salvo groupings, aim wander and range were studied. Optimum launch distances for the rockets were calculated for each set of parameter values. The Ordvac was used in this study to good advantage due to the multiplicity of cases considered.

A method was devised for working with large integers (less than 10^{1500}) on the Ordvac. This method can be adapted for mixed numbers. Its value lies in the retention of all significant digits.

A section of Thor personnel is devoted to the construction of scale models of United States and foreign aircraft and equipment used in the simulation of weapon-target engagements. Solid models which accurately portray the contour of an aircraft and component models which accurately represent the relative size, shape and position of the vulnerable components of the aircraft are constructed within this group. Recently other detailed models such as jet engines, trucks, jeeps, armored cars and locomotives have been constructed. Many of these models are used in B.R.L. studies. Much of the special equipment needed in the various tasks of Project Thor is also developed and constructed within this group.

The fragmentation characteristics of small caliber HE and HEI projectiles, including the effects of charge to metal ratio, type of filler, and application of the resulting data to vulnerability studies

of modern aircraft and aircraft components are currently being studied. The purposes of this study are (1) to improve the techniques of evaluating small caliber contact-fuzed HE projectiles used in air-to-air combat, and (2) to study the optimum combination of fragmentation, blast and incendiary characteristics for such small caliber projectiles.

An evaluation of the effect of fragmentation from A.A. and ground-to-air missiles on the B-47 aircraft is currently being made. Conditional kill probability contours about the aircraft will be determined for the projectiles and missiles. "A", "B" and "C" type kills will be considered.

The vulnerability of several U.S. and foreign aircraft to air-burst A.A. is being determined. These aircraft are either in the design stage or are just becoming operational. "A" and either "B" or "C" damage, depending upon the aircraft type, will be considered.

A survey of data regarding the penetration of aircraft structural material and the defeating of armor by fragments and projectiles is being made. The purposes of this survey are (1) to check the validity and accuracy of existing empirical formulas used in vulnerability studies, and (2) to propose additional theoretical or empirical formulas for conditions not adequately covered. It is expected that, from this study, experiments can be designed which will provide data that are now lacking and which will clarify phenomena associated with penetration.

The protection offered aircrews by cabin stuctures is also be ing considered. This work includes assisting the Ballistic Research Laboratories of Aberdeen Proving Ground in the planning of a test

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program, evaluating the data, and reporting the results in a form suitable for use in aircraft vulnerability and weapons effectiveness studies. The purposes of this work are (1) to determine the vulnerability of personnel in several modern aircraft, (2) to investigate the effect of aircraft type or model upon aircrew vulnerability, and (3) to determine formulas which should be used in weapons effectiveness studies to account for aircrew protection.

In the evaluation of the effectiveness of weapons against targets on the ground it is necessary to estimate the amount of cover afforded such targets by the terrain. To obtain "ground cover functions" five Maryland fields were surveyed by Project Thor personnel. The results, for ranges from the burst point up to 300 feet, are to be published in a forthcoming report. A similar study for rough terrain is being conducted.
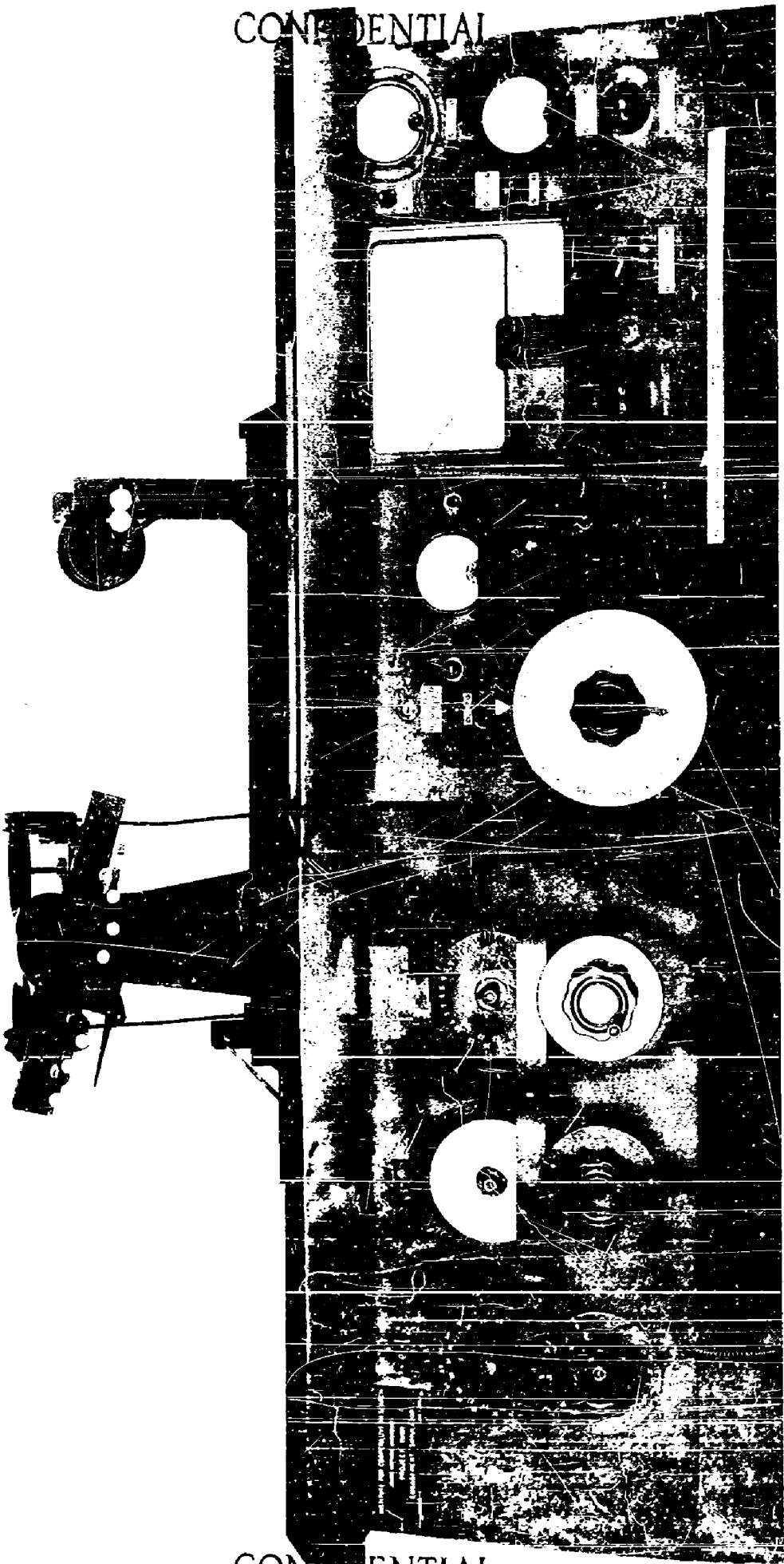
The results of all the current programs will be published

in future Project Thor technical reports.

Reports Published by "Project Thor"

1. Technical Report No. 1   "Damage to Aircraft and Aircraft Components by Fragments of Known Mass and Velocity from Controlled Fragmentation Shell"   June 1949   "Confidential"

2. Technical Report No. 2   "A Critical Comparison of Damage Probabilities to Aircraft Components Predicted from Controlled Fragmentation Shell Data to Those Obtained from 75 mm Air-Burst Shell Experimental Firings"   November 1949   "Confidential"

3. Technical Report No. 3   "Vulnerability of B-29 Aircraft to 120 mm Air-Burst Shell"   February 1950   "Confidential"

4. Technical Report No. 4   "Techniques for Predicting Effectiveness of Certain Classes of Fragmenting Warheads Against Aircraft"   December 1950   "Confidential"

5. BRL Memorandum Report 535   "A Preliminary Fire Analysis of Gasoline-Filled and Gasoline Fume-Filled Tanks and Lines for B-25 Experimental Data Obtained at Aberdeen Proving Ground"   May 1951   "Confidential"

6. BRL Memorandum Report 538   "Vulnerability Areas of B-25 Pilot and Copilot"   May 1951   "Confidential"

7. BRL 763   "C Damage to the B-25 by Controlled Fragmentation Shell"   July 1951   "Confidential"

8. Technical Report No. 5   "An Evaluation of the Effectiveness of Terrier Lot Six Against a Hypothetical Jet Bomber"   August 1951   "Secret"

9. Technical Report No. 6   "Presented Areas of an Average Prone Chinese Infantryman"   March 1952   "Restricted"

10. Technical Report No. 7   "Evaluation of Air-to-Air Rockets; Report on Techniques; Partial Results of an Evaluation of a 5"0 HVAR"   May 1952   "Confidential

11. BRL 836   "An Analysis of Fragment Damage to the B-25 Fuel System"   January 1953   "Confidential."

12. Technical Report No. 8   "Second Report on Damage to B-25 Aircraft Components by Fragments of Controlled Mass and Velocity"   April 1953   "Confidential"

13. Technical Report No. 9   "Evaluation of Air-to-Air Rockets II; Results for 5"0 HVAR Tail-on Study"   February 1953   "Confidential"

14. Technical Report No. 10   "A Method for Evaluating on a High Speed
    Digital Computer A Specially Designed Fragmenting Warhead"
    April 1953   "Confidential"

15. BRL R 729   "Damage to B-25J Aircraft Components by Fragments of
    Known Mass and Velocity for Selected Values of Time After Impact"
    October 1953   "Confidential"

16. Technical Report No. 11   "Evaluation of Air-to-Air Rockets III;
    Results for 5"0 HVAR Tail-on Study for Eight Values of Time After
    Impact"   October 1953   "Confidential"